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Ecology and flora of red sand dunes along the coastline of Visakhapatnam region with a note on the impact of human activities on the scenic beauty of the landscape of the dune area

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ABSTRACT

Red sand dune ecosystem with different land forms and features, and sporadic and scanty vegetation is located along the coastline in Visakhapatnam Region. In this ecosystem, 36 plant species consisting of herbs, climbers/creepers, shrubs, trees and grasses were recorded. The species such as *Indigofera* sp., *Tephrosia* species, *Atylosia scarabaeoides*, *Ipomoea repens*, *Merremia tridentata*, *Aristida funiculata* and *Spinifex littoreus* have been found to be very effective sand-fixers; they stabilize and strengthen dune land forms and control the erosion of dune sand. Aged trees with their well-built root network pose a great threat for dune stability. Human activities involving digging for sand, playing and climbing the dune structures, small vendors vending edible items to people visiting the site and littering have been found to be destabilizing and degrading the stability of dunes making them very prone to erosion by wind and rain water. With these activities, this natural heritage site has lost its scenic ecological beauty and glory. Therefore, it is inevitable to declare this red sand dune system as a "Treasure of the Visakhapatnam Region", take all effective measures for its protection from further degradation and encroachment, and for the restoration of its ecology.

Keywords: Red sand dunes, calcretes, ecology, flora, grasses, human activities.

1. INTRODUCTION

Red sand dunes present near Bhimili in Visakhapatnam District were described as "badlands" for the first time by King (1886) because the dunes

present denudational remnants of great sand banks or isolated banks formed around the sunken hills. Different authors documented the formation of red sand dunes. It was believed that they were formed about 1.8 million years ago during the quaternary era. During this period, sea level oscillations and subsequent rapid climatic and geo-morphological changes involving multiple cycles of depositions contributed to the formation of red sand dunes. The dunes represent ferruginous red loamy soils which are derived from Khondalite suite of rocks, and these soils in course of time became hard and compact. Another explanation was that the sand dunes were formed as a result of top soil erosion from some of the hills of Eastern Ghats in the remote past; the eroded soil simultaneously and subsequently accumulated at the foothills (Seshagiri Rao et al. 2013). Red sand dune sediments deposited over the basement of Khondalite rocks present yellow sands at the bottom followed upward by reddish brown concretion bearing sand unit, brick red sand unit and light yellow sand unit. In course of time, a shift in climate contributed to *in-situ* geochemical alteration of the iron bearing minerals in the red sands resulting in the reddening of the dunes (Nageswara Rao et al. 2006). But, an anonymous report documented that sea level oscillations caused the sea to recede far away from the land and in that process the sea left behind huge piles of clay and silt. In due course, the beach sand swept over the clay and silt covering the previous soil-forming sand dunes. Later, the clay and silt covered over by sand were baked in the sun resulting in the formation of peculiar red sand dunes. In course of time, the action of wind and the force of flowing water caused the erosion of dunes and in effect, the dunes attained the deeply gullied characteristic landscape. Further, the sand dunes attained red colour due to ferrogination of haemitite. In other words, the iron-rich haemitite coated the loose sand particles and the latter attained red color due to oxidation of iron. Another explanation is that the principal cause of the formation of red sand dunes is fluvial process caused by flower water during the period of tectonic quiescence when there was little tectonic activity. One more explanation documented is that the present day red sand dunes are a function of neo-tectonic activity which occurred about 6,000 years ago. The sudden changes in the flow pattern of Gosthani River, the gap in Bhimili ridge and the pattern of fractures are cited as indicators of a series of recent tectonic activities.

The red sand dunes as an ecosystem is an ecological wonder but it is very fragile due loose nature of sediments that make up dunes and also due to day-to-day human activities involving digging, climbing, couples indulging in romance or love, and littering. This state of red sand dunes makes them to be highly vulnerable to wash out by rain water. During rainy season, rain water washes out a huge load of sand sediments which subsequently reach the sea making it bright red. Seshagiri Rao et al. (2013) reported that red sand dunes have been contaminated with heavy metals such as barium, cobalt, chromium, copper, molybdenum, nickel, lead, rubidium, strontium, vanadium, yttrium, zinc and zirconium. The erosion of red sand dunes during rainy season by rain water causes the transport of these heavy metals into the sea, which subsequently change the chemistry of sea water which in turn affects the marine organisms. With this backdrop, the present study was contemplated to record the present state of red sand dune ecosystem, enumerate the native flora and its possible role in the structural stability of dune system, and suggest the measures for the protection of structural and functional features of this sand dune in order to use it as an ecotourism spot and restore the unique scenic beauty of the landscape of this dune system.

2. MATERIALS AND METHODS

The coastal sediments distributed along Visakhapatnam-Bhimili area represent red sediments towards the landside and dune sands and well developed beach towards the sea. Red sand dunes with about 11 sq.km land area located between Visakhapatnam and Bhimili along the shoreline at 90 m elevation above mean sea level formed the material for the study during July-November 2019 and August to January 2020. They are extended up to 2.5 km landward from the beach road that runs along the backshore zone. They are situated about 20 km to the northeast side of Visakhapatnam and 4 km to the southwest side of Bhimili. The dunes comprise different land forms and features such as beach ridges, wave cut terraces, buried channels, gullies, paired terraces, valleys and knick points (Figure 1a-e). Vegetation in the dunes is sporadic and scanty. The entire extent of the dune area was surveyed carefully to record the local flora consisting of different life forms, their value in the stabilization of dunes, and human activities contributing to the degradation of the structural stability and beauty of the landscape. Further, the measures required for the protection of structural and functional features of dunes have been incorporated for their use as an ecotourism spot and nature education.

3. OBSERVATIONS AND DISCUSSION

Phyto-stabilization of red sand dunes: The enumeration of plant species growing in red sand dunes indicates that this dune ecosystem harbors 36 plant species of which 7 are herbs, 6 climbers/creepers, 14 shrubs, 7 trees and 2 grasses (Table 1). Herbs are *Allmania nodiflora* (Figure 2a), *Indigofera* sp. (Figure 2b), *Petalium murex* (Figure 2c), *Phyllanthus* sp., *Tephrosia maxima*, *T. purpurea*

(Figure 2d) and *Tridax procumbens* (Figure 2e). They are seasonal in occurrence, appear during rainy season and form small populations here and there. As they are low ground species, they bind and stabilize the dune sand preventing erosion of the dune at ground level during rainy season. Creepers/climbers are *Atylosia scarabaeoides* (Figure 3a,b), *Cissus vitiginea* (Figure 3c), *Ipomoea reptans* (Figure 3d,e), *Merremia tridentata* (Figure 3f), *Passiflora foetida* (Figure 3g,h) and *Tylophora indica* (Figure 3i). Of these, the last two species are sporadic in occurrence, not bushy and hence have least importance in the prevention of dune sand erosion but all other species with bushy prostrate to semi-erect habit form extensive net work of root system and foliage, and envelope effectively different land forms of the dune system and hence prevent or regulate the erosion of dune sand especially during rainy season. The robust root network ensures these species to maintain enough moisture levels around their root system below ground even during summer season. With this ability, they continue their existence even during dry season and control erosion of dune sand by wind. Shrubs are *Anisomeles indica* (Figure 4a), *Carissa spinarum* (Figure 4b), *Cassia auriculata* (Figure 4c), *Catunaregum spinosa* (Figure 4d), *Chromolaena odorata* (Figure 4e), *Cleome chelidonii* (Figure 4f), *Hyptis suaveolens* (Figure 5a), *Jatropha gossypifolia* (Figure 5b), *Lantana camara* var. *aculeata* (Figure 5c), *Pavonia zeylanica* (Figure 5d), *Sida cordifolia* (Figure 5e), *Triumfetta rhomboidea* (Figure 5f), *Waltheria indica* (Figure 5g) and *Zizyphus oenoplia*. All these species are actually seasonal in occurrence but grow throughout the year here and there depending on the moisture content available around their root system. But, *H. suaveolens* is strictly a seasonal invasive species forming huge populations but it grows only during winter season and hence has no role in controlling erosion of dune formations except adding organic material in the form dead matter. *L. camara* var. *aculeata* is also invasive species and forms abundant populations as an invasive weed. Since it displays prolific growth during rainy season it has an important role in controlling the erosion of dune formations. All other shrubs grow as individual plants or as small populations in scattered form; they appeared to have no role in keeping the dune sands intact by their growth even during rainy season. Among shrubs, *A. indica* and *C. vitiginea* are rare in occurrence in Visakhapatnam region and hence red sand dune system is a good refuge for them. Trees are *Anacardium occidentale* (Figure 6a), *Acacia auriculiformis* (Figure 6b), *Azadirachta indica* (Figure 6e), *Casuarina littorea* (Figure 7a,b), *Ficus* sp. (Figure 6c), *Prosopis julifera* and *Syzygium cuminii* (Figure 6d). Of these, *A. occidentale*, *A. auriculiformis* and *C. littorea* are planted here and there while all others are sporadic in occurrence and growing naturally. All trees with their prolific crown-forming branching pattern add aesthetic appeal and form extensive root system which stabilizes the dune formations initially and subsequently damages the structure and contours of the dunes as and when the latter are partially eroded by wind and rain water. The study indicates that tree planting activities are a threat to the stabilization and sustainability of dune ecosystem. Further, the grasses, *Aristida funiculata* (Figure 7c) and *Spinifex littoreus* (Figure 7d) grow profusely and gradually expanding the extent of their occurrence. These grasses with their adventitious root system act as effective sand binders and contribute to the stability of the dune formations in this entire ecosystem.

Table 1. List of plant species growing in Red Sand Dunes

S. No.	Plant name	Family	Local name
Herbs			
1.	<i>Allmania nodiflora</i>	Amaranthaceae	Godagutti
2.	<i>Indigofera</i> sp.	Fabaceae	Chalapachi
3.	<i>Pedaliium murex</i>	Pedaliaceae	Yenugu palleru
4.	<i>Phyllanthus</i> sp.	Euphorbiaceae	Nelausirika
5.	<i>Tephrosia maxima</i>	Fabaceae	Vempali
6.	<i>Tephrosia purpurea</i>	Fabaceae	Vempali
7.	<i>Tridax procumbens</i>	Asteraceae	Gaddichamanthi
Creepers/Climbers			
8.	<i>Atylosia scarabaeoides</i>	Fabaceae	Pedda adavikandhi
9.	<i>Cissus vitiginea</i>	Vitaceae	Adavidraksha
10.	<i>Ipomoea reptans</i>	Convolvulaceae	Tutikuna
11.	<i>Merremia tridentata</i>	Convolvulaceae	Soorapu teega
12.	<i>Passiflora foetida</i>	Passifloraceae	Tella jumiki
13.	<i>Tylophora indica</i>	Asclepiadaceae	Kukka pala
Shrubs			
14.	<i>Anisomeles indica</i>	Lamiaceae	Aadabeera
15.	<i>Carissa spinarum</i>	Apocynaceae	Chinna vaka

16.	<i>Cassia auriculata</i>	Caesalpinaceae	Thangedu
17.	<i>Catunaregum spinosa</i>	Rubiaceae	Madanamuchettu
18.	<i>Chromolaena odorata</i>	Asteraceae	Kampu rodha
19.	<i>Cleome chelidonii</i>	Cleomaceae	Kukhavominta
20.	<i>Hyptis suaveolens</i>	Lamiaceae	Danthi tulasi
21.	<i>Jatropha gossypifolia</i>	Euphorbiaceae	Nepalamu
22.	<i>Lantana camara var. aculeata</i>	Verbenaceae	Pulicampa
23.	<i>Pavonia zeylanica</i>	Malvaceae	Karubenda
24.	<i>Sida cordifolia</i>	Malvaceae	Bala
25.	<i>Triumfetta rhomboidea</i>	Tiliaceae	Chiru chitrika
26.	<i>Waltheria indica</i>	Sterculiaceae	Nalla benda
27.	<i>Zizyphus oenoplia</i>	Rhamnaceae	Pariki chettu

Trees

28.	<i>Anacardium occidentale</i>	Anacardiaceae	Jidi mamidi
29.	<i>Acacia auriculiformis</i>	Mimosaceae	Australia tumma
30.	<i>Azadirachta indica</i>	Miliaceae	Vepa cheetu
31.	<i>Casuarina littorea</i>	Casuarinaceae	Sarugudu chettu
32.	<i>Ficus sp.</i>	Moraceae	Ravi chettu
33.	<i>Prosopis julifera</i>	Mimosaceae	Sarkar tumma
34.	<i>Syzygium cuminii</i>	Myrtaceae	Neredu

Grasses

35.	<i>Aristida funiculata</i>	Poaceae	Chipurugaddi
36.	<i>Spinifex littoreus</i>	Poaceae	Ravanasuruni meesalu



Figure 1. Red sand dunes: a. & b. Landscape of the dunes, c. & d. Stabilized dune, e. Internal structure of the dune.



Figure 2. Herbs: a. *Allmania nodiflora*, b. *Indigofera* sp., c. *Pedalium murex*, d. *Tephrosia purpurea*, e. *Tridax procumbens*.

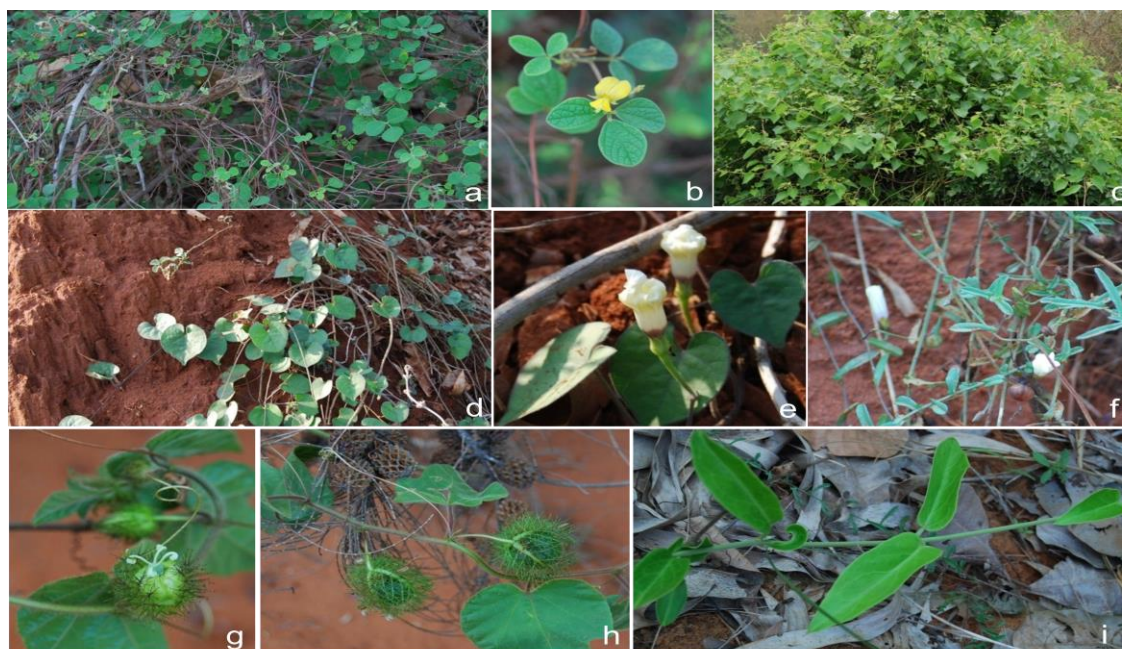


Figure 3. Creepers/climbers: a. & b. *Atylosia scarabaeoides*, c. *Cissus vitiginea*, d. & e. *Ipomoea repens*, f. *Merremia tridentata*, g. & h. *Passiflora foetida*, i. *Tylophora indica*.

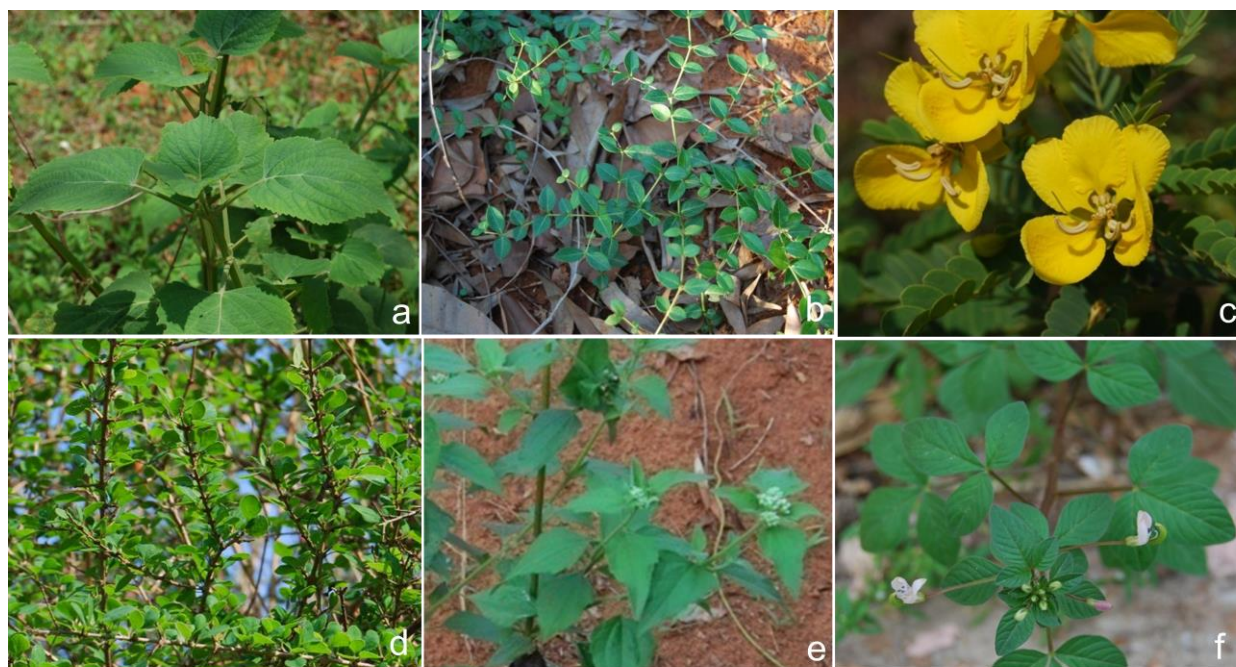


Figure 4. Shrubs: a. *Anisomeles indica*, b. *Carissa spinarum*, c. *Cassia auriculata*, d. *Catunaregum spinosa*, e. *Chromolaena odorata*, f. *Cleome chelidonii*.

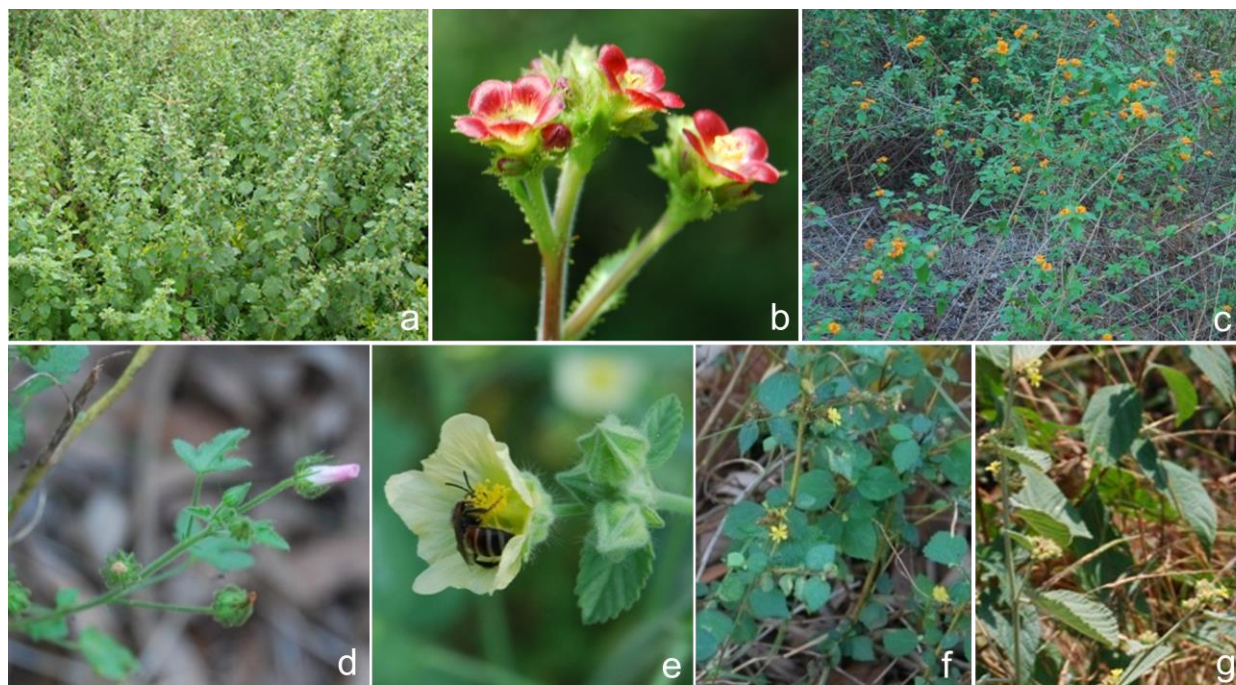


Figure 5. Shrubs: a. *Hyptis suaveolens*, b. *Jatropha gossypifolia*, c. *Lantana camara* var. *aculeata*, d. *Pavonia zeylanica*, e. *Sida cordifolia*, f. *Triumfetta rhomboidea*, g. *Waltheria indica*.



Figure 6. Trees: a. *Anacardium occidentale*, b. *Acacia auriculiformis*, c. *Ficus* sp., d. *Syzygium cuminii*, e. *Azadirachta indica*.

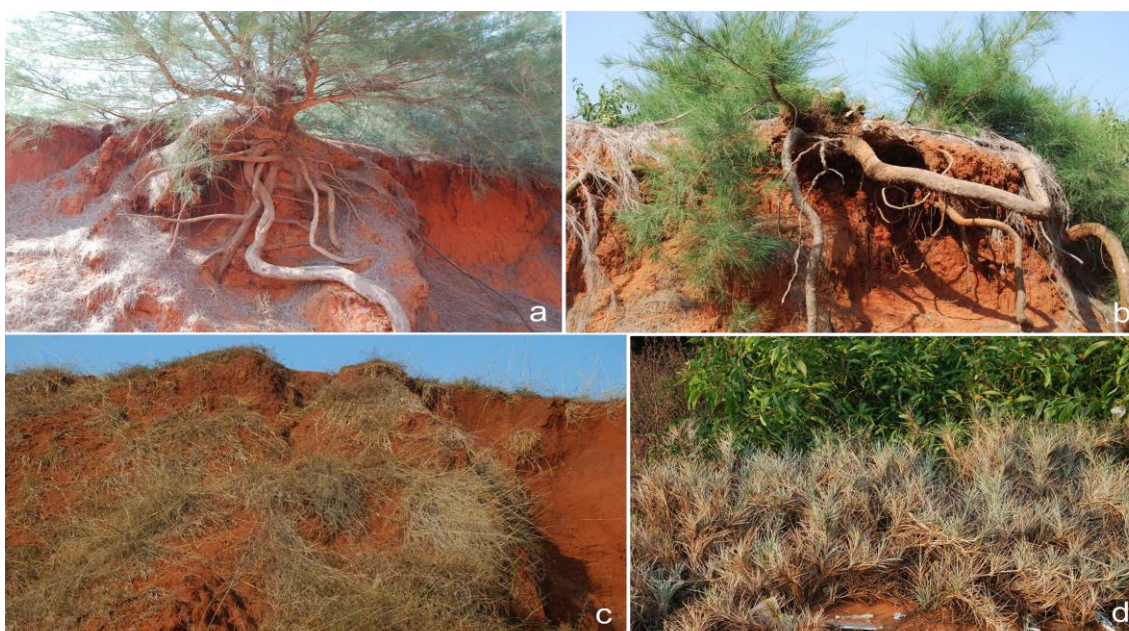


Figure 7. Trees: a. & b. *Casuarina littorea* – aged trees root out the red sand structures, Grasses: c. *Aristida funiculata*, d. *Spinifex littoreus*.



Figures 8. Red sand dune as waste dumping site: a-b. Plastic and paper debris defacing the scenic beauty, c. & d Empty coconuts rolling on the floor of red sand dunes.

Rao et al. (1993) reported that the calcareous and non-calcareous material, terrestrial deposits, coastal deposits, emergent marine deposits and even in igneous metamorphic rocks contain calcretes which comprise of limestone formed by the cementation of soil, gravel, sand, shells and calcium carbonate accumulated by evaporation and escape of carbon dioxide from vadose water. The calcretes exhibit different distinct structural types such as rhizo-concretionary, massive and mottled; the formation of these structural types is dependent on the maturity of the profile and the influence of vegetation. Klappa (1980) used the term "rhizolite" for a rock showing structural, textural and fabric details determined largely by the activity of plants roots. Wright and Tucker (1991) and Wright et al. (1995) documented that the word "rhizogenic" is used to describe calcretes composed of largely or wholly of textures formed due to calcification on, in or around roots as root calcification structures are very common constituents in many calcretes. Jagannadha Rao et al. (2016) attributed the formation of calcretes to the process initiated by the evaporation and deposition of calcium carbonate in root systems due to capillary intake of ground water super-saturated with calcium carbonate by the root systems of plants and other vegetation. These studies suggest that vegetation consisting of different life forms have an important role in the formation different of calcrete structures. The differences in calcrete structures indicate the function, length and breadth of root structures which reach down to fresh water table. In this study, different life forms with different extents of root system, and prostrate and climbing/creeping habit in case of herbs, creepers and some shrubs if exist continually in the pockets of dune sands where they grow could form calcretes over a period of time while stabilizing red dune sand structures. Grasses, *A. funiculata* and *S. littoreus* growing here are very important in keeping the structural integrity of different dune structures due to their adventitious root system that acts as effective sand binder and their ability to grow throughout the year with very low moisture content in the dunes. Lee et al. (2020) also reported that *S. littoreus* as a procumbent sand-fixing perennial grass has an important role in dune building as it has the ability to control sand erosion and capture the sand in building the dune. In this context, it is reasonable to state both *A. funiculata* and *S. littoreus* are effective sand-fixing grasses and ensure the stabilization of red sand dune structures while controlling their erosion mediated by wind and rain water. Therefore, the study recommends that the herbs, *Indigofera* sp., *Tephrosia* species, *Atylosia scarabaeoides*, *Ipomoea repens*, *Merremia tridentata*, *A. funiculata* and *S. littoreus* be enabled to grow either naturally or by planting so that red sand dunes can be restored to their natural state.

Human activities and their impact on destabilization and degradation of red sand dunes: Local people visit red sand dunes as an ecologically pleasing natural heritage site. But, the activities such as digging for sand, playing and climbing the dune structures, couples indulging in romance or love, street or small vendors vending edible items to people visiting the site and littering are quite common. Plastic and paper waste (Figure 8a,b), empty coconuts (Figure 8c,d) and liquor bottles are the common items that make up the waste. These activities are contributing to the destabilization and erosion of dune structures, and making them to lose

aesthetic appeal and treat them as waste disposal site. With these activities, this natural heritage site has lost its scenic beauty and glory. Therefore, it is suggested that the red sand dune ecosystem should be protected by declaring it as a "Treasure of Visakhapatnam". Further, a comprehensive document detailing the history of geo-morphological processes of the red sand dunes and ecological conditions that enable the existing plant and animal species is to be brought out to create awareness about of the importance of "the unique red sand dunes" to realize their importance and protect them from further degradation and encroachment. Since these dunes are in ecologically degraded state, their structural stability and ecology should be restored by planting the recommended plant species and declaring the area as one of the ecotourism destinations.

4. CONCLUSIONS

Red sand dunes constitute a unique ecosystem which is a natural treasure located along the coastline in Visakhapatnam Region. The dune system presents different land forms and features with sporadic and scanty vegetation. Enumeration of flora of the dunes indicated that 36 plant species consisting of herbs, climbers/creepers, shrubs, trees and grasses occur here. The species such as *Indigofera* sp., *Tephrosia* species, *Atylosia scarabaeoides*, *Ipomoea repens*, *Merremia tridentata*, *Aristida funiculata* and *Spinifex littoreus* are very effective sand-fixers; they stabilize and strengthen dune land forms and control the erosion of dune sand. Young trees do not pose any threat for the stability of the dunes but aged trees with their well-built root network pose a great threat for dune stability. Human activities involving digging for sand, playing and climbing the dune structures, small vendors vending edible items to people visiting the site and littering have been found to be destabilizing and degrading the stability of dunes making them very prone to erosion by wind and rain water. With these activities, this natural heritage site has lost its scenic ecological beauty and glory. Therefore, it is inevitable to declare this red sand dune system as a "Treasure of the Visakhapatnam Region", take all effective measures for its protection from further degradation and encroachment, and for the restoration of its ecology.

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Ethical approval: The ethical guidelines for plants & plant materials are followed in the study for species collection & identification.

Conflict of Interest: The authors declare that there are no conflicts of interests.

Data and materials availability: All data associated with this study are present in the paper.

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